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Carbon Nanotubes in Chemical Analysis

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Abstract: The impact of carbon nanotubes in the chemical analysis is reviewed. It is shown that carbon nanotubes may be used as a target analyte as so as analytical probe. Carbon nanotubes may be used in a wide range of analytical sciences such as, separation sciences chromatography, electrochemistry and spectrophotometery. However, while nanotubes are being tested for used in a new field, their truly enormous potential has yet to be realized.

Key words: Carbon Nanotubes · Analytical Chemistry

INTRODUCTION

Carbon nanotubes are novel and interesting nanomaterials in the field of nanometer research because of their many unique electronic, mechanical and chemical properties. These characteristics have made nanotubes the subject of intensive investigation since their discovery. In fact, carbon nanotubes may display metallic and semiconducting electron transport properties and they possess hollow cores, which can store guest molecules. Carbon nanotubes can be considered to be hollow graphitic nanomaterials comprising one (single-walled carbon nanotubes, SWNT) or multiple (multi-walled carbon nanotubes, MWNT) layers of graphene sheets (Fig. 1). SWNT are considered to be one-dimensional molecules due to their high length to diameter ratio [1], wile MWNT are a collection of concentric SWNT. The application of nanotubes in different areas is clearly hampered by the difficulties involved in producing large amounts of the pure material. The production methods currently available produce nanotubes with various lengths, diameters and structures, resulting in a lack of consistency in the tube's properties and, therefore, uncertainty as to the applications that they can be used for. Carbon nanotubes synthesis techniques may be classified under three major categories: laser ablation, catalytic arc discharge and chemical vapor deposition [2]. For analytical purposes, the latter is probably the most interesting, because it permits synthesis on a surface of vertically-aligned carbon nanotubes. In attempt for gaining greater yields, combination of different oxidizing agents with or without the use of acids were used in liquid–phase oxidations, such as $KMnO_4$ [3], H_2O_2 [4] or bromine water [5] etc. Ultrasonication was combined with almost every technique because treating the sample in ultrasonic bath can free many tubes from the particles which are originally stuck together [6]. A considerable progress in purifying SWNT was made but this has not been the case for MWNT because of difficulties in obtaining larger quantities of pure sample material [7]. Their use in sample clean-up procedures or analyte preconcentration via either filters/membranes or a sorbent packed material is also considered. Ajayan and co-workers [8] reported the fabrication of monolithic hollow cylinders constituted by radially aligned carbon nanotubes walls. The synthesis process permitted the creation of cylinders with diameters and lengths of up to several centimeters. MWCNTs have been characterized as superior sorbents for removing dioxins for environmental protection [9]. CNTs can also be utilized for sorption of inorganic ions (e.g., MWCNTs show high efficiency in removing Pb^{2+}, Cd^{2+} and F^- from aqueous solution after oxidation treatment with nitric acid

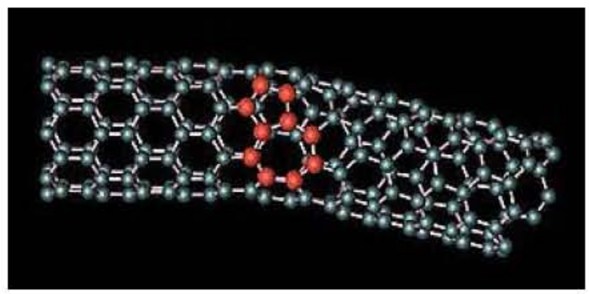

Fig. 1: The joining of two carbon nanotubes with different electrical properties to form a diode has been proposed [27]

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[10]. In 2001, Long and Yang observed that dioxins, which present two benzene rings, were strongly adsorbed on MWNTs. In fact, the authors suggest that MWNTs are an ideal adsorbent for dioxin removal [11]. The MWNTs have also been used for solid-phase extraction of three endocrine disruptors: bisphenol, 4-n-nonylphenol and 4-tertoctylphenol. The three analytes were quantitatively isolated from environmental water samples on an MWNT-packed cartridge and further eluted with suitable amounts of methanol [12]. The unique properties of carbon nanotubes make them extremely attractive for the fabrication of chemical sensors, in general and electrochemical detection, in particular. Recent studies have demonstrated that carbon nanotubes can enhance the electrochemical reactivity of biomolecules and promote the electron–transfer reactions of proteins. The high conductivity of carbon nanotubes to surface adsorbates permits their use as highly sensitive nanoscale sensors [13, 14]. Carbon nanotubes, both SWNT and MWNT, can be vertically aligned on the electrode surface. In this case, the carbon nanotubes act as molecular wires, allowing electrical communication between the underlying electrode and the redox enzyme or biomaterial. The direct electron transfer between the biomaterial and the electron surface obviates the need for redox mediators and is thus extremely useful in sensing devices. Especially large number of applications can be found in the literature on applications of CNTs as electrode materials or modifiers of conventional working electrodes in analytical voltammetry. These applications, pioneered by work of Britto *et al.* [15] on reversibility in the oxidation of dopamine using CNTs as electrodes, concerned both amperometric and voltammetric determinations, as well as the electrochemical biosensors and the voltammetric stripping methods. These applications have already been reviewed [16-21], Among other methods of modifying working electrode surfaces with CNTs are the incorporation of MWCNTs in 1-octyl-3-methylimidazoline hexafluorophosphate gel and in a layer of electropoly- merized polyaniline [22] and also preparation of paste comprising SWCNTs and mineral oil [23, 24]. Modifying a working electrode with CNT allows the overlapping response of uric acid and L-ascorbic acid to be resolved [25] and these signals to be resolved from the anodic peak of dopamine [26], which was successfully applied to the dopamine assay of human blood serum. CNTs exhibit excellent thermal stability in inert atmospheres, where they remain stable at up to 1200°C. This property is the basis of their use as stationary phases in gas chromatography. The behavior of purified MWNTs as column packing material for gas chromatography has been considered. Carbon nanotubes have also been used as a component of the background separation electrolyte in capillary electrophoresis. In this case, the carbon nanotubes present in the buffer act as a pseudostationary phase. The different partitions of analytes between the buffer and the nanotube surface, together with the different migration velocities of the nanotubes and the free analytes, are responsible for the electrophoretic separation.

Carbon nanotubes possess useful features with a view to improving the analytical process. Their potential roles in the development of new tools for analytical science, arranged in terms of complexity of design and integration. This and other aspects of the analytical uses of CNTs are discussed in the current review.

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